Excessive Kiln Temperatures Cost Heavily in Degrade

By W. K. LOUGHBOROUGH, Engineer; W. L. GREENHILL, Research Student; and IAN LANGLANDS, Research Student

Forest Products Laboratory, Forest Service, U. S. Department of Agriculture

The operator who maintains too high a temperature in the kiln, especially when any portion of an individual board is above 25 per cent moisture content, will lose more money through degrade of stock than he will save through reduction of drying time. Although the Forest Products Laboratory has known this fact for years and all along has had plenty of evidence to substantiate it, recent research has added one more bit of confirmation. This research dealt primarily with a strength property, tension perpendicular to the grain, that ordinarily is overlooked. The results of this and of earlier work show that the strength of wood perpendicular to the grain varies with temperature, as well as with moisture content, and that certain drying stresses at high temperatures frequently cause severe checking. Consequently the stresses resulting from excessive drying temperatures are too destructive to be tolerated in commercial practice, and for this reason the temperatures that cause them are not justified.

A hardwood, beech, was selected for the latest investigative work on this subject. Accurate determination of many of the strength properties of beech shows that this species is not at all exceptional in other strength properties, among commercial woods, and so presumably is not exceptional in the property under consideration here. Further, it was selected for this experimental work largely because it is refractory in drying and hence would be more likely to show the cause of the drying troubles that appear in all woods, in different degrees, than a species less refractory. This limited study, taken by itself, is therefore indicative rather than conclusive, but adding to it the results of other work permits the statement that the chief deductions reached it this study probably apply in general to other commercial hardwoods and probably apply also, although perhaps to a somewhat less extent, to commercial softwoods. Hence every lumber manufacturer who kiln-dries green stock will find in this report why conservative drying temperatures pay dividends.

Figure 1 shows a typical specimen in one group of 44 pieces. The test specimens were cut across the grain from flat-sawn boards, and were pulled apart across the grain. Suitable measurements were taken during the operation. The ruptures followed ray cells. All specimens in each group were heated to a definite temperature in a definite relative humidity, and these conditions were maintained while the specimen was in the testing machine. Although values of moisture content ranging as low as 7 per cent were used, only the results for green stock are presented here, since the other results are so similar that giving them is unnecessary for the present.

Both checking and honeycombing are failures in tension perpendicular to the grain. Checking occurs in the relatively thin surface layers of the drying piece while they are under tensile stress, in the first part of the drying period, and similarly honeycombing does not occur in the relatively thick core until it too has come under tensile stress, in the second part of the drying period; during the first part of the drying period the core yields somewhat under the compressive stress to which it is then subjected but it does not rupture until the compressive stress has changed to tensile. Since these drying failures are always in

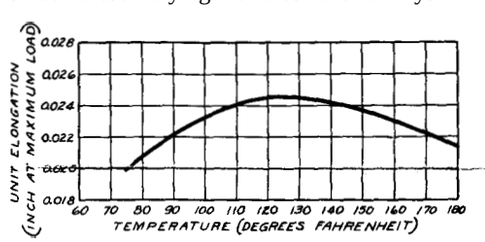

Figure 2—Variation of unit elongation at maximum load with temperature, for green beech.

tension, the corresponding strength in compression perpendicular to the grain must be more than adequate to resist the drying stresses placed upon it and consequently it need not enter this discussion, which is primarily concerned with the ruptures that occur in practice.

Table 1, a comparison of the properties that oppose checking and honeycombing, shows that going either up or down from the best drying temperature, about 124° F. for the samples tested, decreases the resistance of the green wood to checking. The outer shell of a drying piece is placed in tension as it loses moisture, a fact well known to kiln operators, and in consequence it stretches. If it stretches enough no checks will develop. If the elongation across the grain is insufficient, however, checks do develop. The last two columns of the table record the surprising fact that air seasoning beech at about 75° F. causes almost as much seasoning degrade as kiln-drying it at the highly excessive initial temperature of 180°F. A drying temperature at the start of about 124° F. holds this degrade to a minimum, when kiln conditions other than temperature remain constant. Because the figures given are percentages, the values in each column art comparable among themselves but are not comparable with values from other columns

TABLE 1.—Comparison of the strengths of green beech in tension perpendicular to the grain and the elongations, at three temperatures.

Temperature °F.	Load at— Elastic limit Per cent	Load at— Maximum Per cent	Elongation at— Elastic limit Per cent	Elongation at— Maximum Per cent
75	124	...	92	...
75	...	125	...	81
124	100	...	100	...
124	...	100	...	100
180	49	...	87	...
180	...	57	...	86

The value of 124° F. comes from Figure 2. This graph has a definite maximum which, of course, determines the best initial drying temperature. Although the tension perpendicular to the grain that the wood will support without rupture is the principal criterion for drying conditions, this strength does not come into play until the wood has exhausted its first defense against checking and honeycombing, its yield across the grain. Other curves like Figure 2, not shown here, determines the best drying temperature for. moisture-content values below the fiber-saturation point.

Figure 3, which plots the change in maximum load across the grain with change in temperature, would lower the most advisable initial drying temperature of about 124°F. if the figure were considered by itself. In this graph the ultimate unit tensile stress that green beech will sustain across the grain at 60°F drops to less than half as much at 180°F., while at 124°F. it is still close to the high value although not equal to it. This graph leaves no doubt about the fact that high initial drying temperatures should be used with caution if at all.

The commercially permissible maximum initial drying temperature varies somewhat with the species. The drying schedules published in the Kiln Drying Handbook, U. S. Department of Agriculture Bulletin

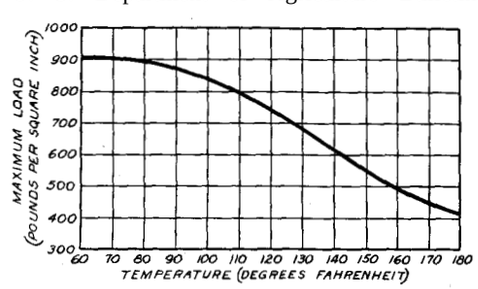

Figure 3 - Variation of maximum load With temperature, for green beech. The graph for the variation of modulus of elasticity is similar, although it drops even more.

1136, take account of this fact. These schedules also allow for the additional fact that the maximum permissible temperature becomes higher as the moisture content of the lumber drops below the fiber-saturation point. These schedules are somewhat conservative; the mazimums they specify are entirely sfe. An experienced and careful operator, one who consistently checks his results closely, may be able to exceed these temperatures without excessive degrade, but the Forest Products Laboratory recommends using the schedules as they stand unless higher temperatures and lower relative humidities have been justified by verified experience.

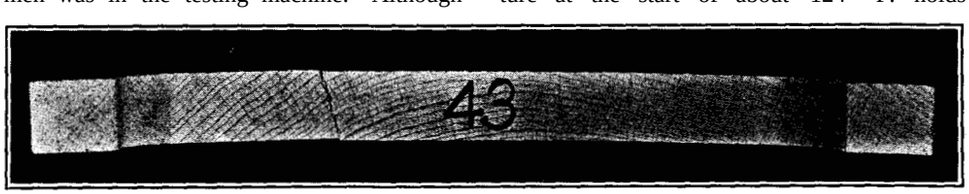

Figure 1 –A typical test piece of beech after fracture across the grain.

(Reprinted from Southern Lumberman, Nashville, Tenn., issue of April 15, 1932)